2. Environmental condition and conflicts of the cross-border area

2.1. Climate and environment

Viktória Blanka, Dragan Dolinaj, Andrea Farsang, Károly Fiala, Mladen Jovanovic, Tímea Kiss, Zsuzsanna Ladányi, Imre Pálfai, Dragoslav Pavić

The study area, south Hungary and Vojvodina is situated in the southern part of the Carpathian Basin (Fig. 2.1 on page 20) Similar physical-geographical features describe the area. The major part of the area is flat, smaller mountainous areas are only located in the south of Vojvodina (Fruška gora and Vršac). The study will focus on the flat areas, since droughts lead to serious natural and economic problems mainly on these areas. Before presenting the results of the research, the most important environmental features of the area regarding droughts will be summarized so that it can give us a clear picture of the natural background of the issue researched.

Climate

The study area belongs to the Köppen-Cf (warm moderate, with even distribution of precipitation during the year) or Trewartha-D.1 (continental climate with longer warm season) climate zones. The annual mean temperature is around 11 °C in the study area with the annual amount of precipitation reaching 500-600 mm. In the hottest month, in July, the mean temperature is in general around 21 °C and 23 °C, the precipitation in the summer half-year is at about 300 mm (Smailagic et al. 2013, OMSZ 2014).

South Hungary

In the Hungarian part of the study area the temperature timeline has shown variability occurring from year to year. However, an increasing tendency of the temperature can be clearly detected. Warmer years following the 1990s occurred more frequently. In the timeline, mean temperature for 2000 and 2007 were the highest. Splitting the distribution of the mean temperature values of the studied period (1961-2012) into two periods, the entire catchment area has shown signs of warming up (Fig. 2.2 on page 22). The southern parts reveal this more significantly, the annual mean temperature increased by 0.8 °C. There is an essential difference between the temperature changes within a year. Mean temperature for summer months (from June to August) and for winter months (from December to February) have shown an increasing trend.

The last period with outstanding amount of precipitation was at the end of the 1960s. For 20 years after 1970 the weighted rainfall amounts were below or around the mean value and years with extreme precipitation were completely missing. The year 1991, but mainly the end of the 1990s (1998 and most preferably 1999) then 2001, 2004, 2005 in the 2000s and the year of 2010 with the highest precipitation brought changes. However, in spite of the few high precipitation years it can be stated that not only the amount of precipitation decreased in the studied period (1961-2012) but – at a greater rate - the number of years with extreme precipitation (1999 and 2010 were like this) as well. Changes can be detected in terms of the amount of yearly mean precipitation: the isoline of 550 mm ran through the middle of the study area in the first period until 1987, then this isoline shifted to the west in the next period until 2012 (Fig. 2.2 on page 22).This may not be regarded as a substantial difference, but in certain parts of the catchment area it could mean water shortage of 20-30 mm annually. In terms of the precipitation conditions of the area, years that are drier than the average occur more frequently, the temporal distribution of precipitation is less favourable. Especially in the summer periods extreme precipitation events occur in a short time, which led to the increase in the run-off rate of valuable water resources.

Vojvodina

An increasing trend of annual mean temperature can be observed in Vojvodina based on data of the past 50 years (Table 2.1 on page 24). The period of 1951-2012 can be characterised by a temperature rise of 1 °C on average. The highest rate of temperature increase was pointed out for the north-western part of the area, at Sombor station, while less increase occurred in the south of the area. Precipitation change for the same period did not show the same tendency in the entire Vojvodina. Vršac and Sremska Mitrovica stations show a decreasing tendency, while a positive trend was identified for the other stations. The most significantly increasing amount of precipitation was reported for Novi Sad (catchment area of the Danube), the most decreasing trend described Sremska Mitrovica (catchment area of the Sava).

Geomorphology of the study area

The study area can be divided into two larger parts: the former alluvial fan of the Danube in the west, and the floodplain of the River Tisza in the east; the two areas differ greatly regarding their formation, age and geomorphologic forms as well, since today the alluvial fan of the Danube-Tisza Interfluve is dominated by blown sand and loess forms shaped by the wind, while fluvial forms can be found along the River Tisza (Fig. 2.3 on page 25).

The geomorphologic features of the Danube-Tisza Interfluve

The Danube-Tisza Interfluve can be considered a Pleistocenic alluvial fan of the Danube and its western tributaries (e.g. Sió, Sárvíz) (Borsy 1977). Blown sand covers the northern area of the alluvial fan to the north of the Subotica-Palić-Šupljak line (Kiskunság), while the loess area of Bačka can be found to the south of the lakes. Accordingly, the forms, the soil types, the flora, and the hydrological features of north and south differ.

The Danube flowed towards the south-east after the Visegrád Gorge from the beginning of the Pleistocene, and it built its alluvial fan gradually, putting thicker and thicker layers of smaller and smaller grain towards the east (Sümeghy 1944). The uplift of the central part of the Danube-Tisza Interfluve, together with the subsidence of the area around Mohács, meant a landmark in developmental history. As a result, the Danube shifted to the west in the middle or at the end of the Wurm Glacial Period, and it adjusted to its flow of today, from north to south, eroding the plains along (Duna-menti Plains) (Sümeghy 1944, Bulla 1951, Pécsi 1967). The alluvial fan lost its active streams with the western relocation of the river, at the same time it became higher compared to its environment, as a result of the incision of the Danube. Thus, the alluvial fan became poorer in surface water and groundwater, as well, which was enhanced by the fact that it is the driest area of the Carpathian Basin. Due to the effects of these factors, blown sand movement and loess formation could start.

The problem of aridification, present until today, originates from landscape evolution of the area on one hand, on the other hand, from the high proportion of water-permeable eolian sediments of loose structure. At the same time, poorly drained layers, like lime sludge, calcrete, and clay were formed in the low-lying depressions as an effect of salt lakes and slow streams (Molnár 1961). Accordingly, moorland and wet areas could be found in the depressions before the drainage of the 19th and 20th centuries. These recesses disposing of aquitard layers may be potential spaces of water retention in the future. The artificial water supply of the area is hindered by a feature of landscape evolution, that is, the alluvial fan declines towards the east, towards the present riverbed of the River Tisza, while the plains along the Danube in the west are situated 50-60 m lower (Fig. 2.4 on page 26). Thus, water supply of the Danube-Tisza Interfluve from rivers can be cumbersome and expensive, since it cannot be solved gravitationally.

The blown sand area of Kiskunság

The eolian activity in the Danube-Tisza Interfluve could become the dominant process of the after stopping the formation of the alluvial fan formation. Sand movements in the Pleistocene could affect large areas, nevertheless we cannot consider them continuous, since colder periods with rare vegetation and milder periods with more dense vegetation alternated, and so, the conditions for eolian processes in forming surface was changed in those periods. A significant sand movement took place in the Upper Pleniglacial (Gábris 2003), during the last glacial maximum (Sümegi 1993), and in the Older and Younger Dryas (Gábris 2003).

The Holocene with its increasingly favorable climate conditions and denser vegetation did not facilitate blown sand movements in general. However, the Boreal phase of the Holocene was warm and dry, the groundwater levels decreased and the forest area was reduced, all of which together made the eolian formation possible in the Danube-Tisza Interfluve (Gábris 2003, Nyári and Kiss 2005). Owing to human activity, sand movements also occurred in historical times, for example, in the late Bronze Age, in the 6th-8th centuries, in the Árpád Age, in the times of the Turkish occupation, and in the 18th-19th centuries (Lóki and Schweitzer 2001, Gábris 2003, Nyári and Kiss 2005, Antal 2010). But the generated forms are much smaller than the earlier ones, since the present climate does not promote extended sand movements, so they could occur in smaller sites only (Borsy1977). Furthermore, sand movements of historical times also indicate the fact that if vegetation is destroyed, or groundwater level decreases because of aridification, sand movement can happen in the higher, barer areas also in the future.

A mosaic-like structure of forms characterises the vast area of the Danube-Tisza Interfluve, since the creation of forms was also influenced by several local factors (e.g. topography, depth of groundwater, characteristics of vegetation, duration of sand movements). The sand forms are arranged into northwest-southeast direction by the north-western wind, in a way that the positive forms create island-like groups, while there are extended deflationary depressions and plain areas around them.

In the Danube-Tisza Interfluve the number of blown-out depression–hummock–residual ridge groups is the highest (Borsy 1977). The blown-out depressions are elongated oval deflation basins of 20-500 m long; their width (25-200 m) depends on the density of vegetation stabilizing their sides. The blown-out depressions are usually shallow (app. 1.5 m) forms; their depth can be greater (max. 8 m) only in areas with a very deep level of groundwater. In the areas covered by loess sheet, 1 km-long blown-out depressions can also be found. It is a common phenomenon in the entire Danube-Tisza Interfluve that there is no hummock connected to the ends of blown-out depressions; rather, blown-out depressions follow each other like chain links.

The deflation depressions are forms also created by blowing out, but much bigger than the blown-out depressions. Because of their large size (length: 5-8 km, width: 1-2 km), smaller forms and parabolic dunes could be formed in their bottom. The deflation depressions were thought to be earlier Danube branches because of their large size, and northwest-southeast direction, but the sediments of the Danube are situated much lower (Mih__á__ltz 1953, Molnár 1961). The residual ridges have remained between blown-out depressions, and they show the height of the earlier surface. Their length varies between 10 and 300 m.

The sand blown out of a blown-out depression can be formed into a crescent-shape hummock, the height of which is 2-8 m on average, but in larger accumulation fields a hummock of 15-18 m is not rare (Borsy 1977). The hummocks can be arranged one behind the other and can form hummock rows. It is a characteristic feature of the Danube-Tisza Interfluve that hummocks concentrated into so-called accumulation fields that stand out of their environment like islands. Sand movement can easily start in these elevated areas, if their sparse vegetation gets damaged. The sand blown out of the blown-out depressions could have dispersed in large areas, so, sand sheets were created in this way. These are relatively thin (0.5-2 m) sand accumulation layers that could have covered large areas.

Occasionally, hummocks were further moved by strong winds, and created parabolic dunes when they merged. Since vegetation could stabilize the ends of the parabola, these part cannot be transported, while the winds move further the higher (max. 20 m), thus drier, centre part. In this way, the apex of the parabolic dune could move more quickly, and hairpin-like parabolic dunes were created.

The loess area of Bácska/Bačka

Only the northern part of the loess covered Bácska/Bačka region is situated in Hungary, the majority of its area is in Serbia. Its surface is covered by several meters of loess that gradually thickens towards the south. The loess layer often mixed with blown sand, mainly in the northern edges, or thinly covers blown sand forms (Pécsi 1967).

The formation of loess in Bácska/Bačka started at the beginning of the Pleistocene, lasted till the end of the Ice Age, and resulted in almost 20 m-thick loess layers (Markovic et al. 2008). To the Bácska/Bačka loess was transported by northern winds from distant and highly diverse source regions. Typical loess can be found in the higher areas (e.g. loess plateau of Titel), while loess-like sediments can be found in the valleys, floodplains, and at the foothills of mountainous areas (e.g. Fruska Gora). There are six main loess plateaus in Vojvodina, isolated from each other, and two of these can be found in the study area.

It is generally true for loess areas that an almost flat surface is created after loess formation due to the fact that loess smooth elevation differences at sedimentation. This kind of surface was eroded by the streams flowing towards the River Tisza in northwest-southeast direction, which formed shallow valleys with wide bottoms. Muddy and calcareous areas were created with poor water permeability in this way, similarly to the northern part of the Danube-Tisza Interfluve, thus valleys are capable of temporary surface water storage.

The dissolution of carbonate cementing quartz grains, and the removal of quartz grains play a key role in the erosion of loess. As a result of this process, bowl-shaped loess dolines have been formed on the surface (Fig. 2.5 on page 30). They are 1-2 m deep, and their width can reach 200-400 m. They are wetter areas at spring time compared to their environment due to the enrichment of silt-clay sediment at their bottom. The loess plateaus (e.g. Titel) are separated by a steep edge from the neighbouring, usually floodplain areas. Along steep edges find steep-walled, 5-6 m deep loess wells of 1-2 m in diameter can be found (Fig. 2.6 on page 31). The water - creating the loess well - seeps under the surface, while it dissolves carbonate, and transports quartz grains. Since water can get to the surface easily at the edges, these forms are relatively quickly formed, but can easily collapse, as well.

The geomorphologic features of the Lower Tisza Region

Floodplain formation could only have occurred in the narrow (10-30 km) band between the alluvial fans of the Danube and the Maros, and the floodplain area was further narrowed by the incision of the River Tisza (4-10 km) afterwards. The fluvial processes were driven here by the intensive or less intensive subsidence of the area and these processes were also influenced by constantly changing water-, and sediment transporting capacity of rivers. Moreover, the estuary region of the Maros has gradually been shifted in the past 19 thousand years between Szarvas and Novo Milosevo-Kikinda, which can have influenced the dynamics of the River Tisza on the upper and lower sections of the estuary (Kiss et al. 2014).

The Lower Tisza Region has also been filled up significantly because of the cyclic subsidence; the thickness of Pleistocene layers reaches 500-600 m (Miháltz 1967, Rónai 1985), while the Tisza has formed its floodplain between the alluvial fans of the Danube and the Maros. However, floodplain formation was not uninterrupted, because tectonic activity, climate, and vegetation continuously influenced water-, and sediment transporting capacity, which resulted in an incision from time to time. The processes resulted in three floodplain levels along the Tisza, and the river flows in the axis of the lowest level today. This can be considered disadvantageous from the point of view of aridification, since water from the Tisza can only be elevated by pumping to the higher levels. However, the palaeo-channels with clay beds can serve as excellent water storages, since rainwater or groundwater can be stored in them for a longer time.

The high floodplain level (level C) can be followed on the western side almost continuously, while the alluvial fan of the Maros has partly buried it on the eastern side. This floodplain was an active floodplain of the Tisza at the end of the Pleistocene, because the palaeo-channels were active here about 10-18 thousand years ago (Kiss et al. 2013, 2014). These channels were enormous (L: 6-14 km /meander length/, H: 5-10 km /chord length/), which indicates that the

Tisza had significant discharge. (Q_b=12-15 thousand m^3/s /bankfull discharge/). The River Maros also contributed to this large discharge, since it could have joined the Tisza in the northern and central parts of the Lower Tisza Region.

The incision of the mid-floodplain level (level B) happened at the Pleistocene-Holocene boundary (Kiss et al. 2013). This level is situated 1-2.5 m under level C; it runs nearly parallel to the latter. The palaeo-channels located at its surface (e.g. around Deszk and Novi Bečej) were formed 8-10 thousand years ago, at the beginning of the Holocene. The size of the meanders (R_c= 3-4 km /radius of curvature/, L= 7-12 km, H= 5-7 km) is smaller to a certain extent than those of the older channels, but still indicate a significant water discharge (Q_b= 11-13 thousand m^3). The large water discharge of the Maros, which used to flow into the Lake Hód palaeo-channel at that time at Hódmezővásárhely, can have contributed to the large discharge of the Tisza (Kiss et al. 2013).

The formation of the low floodplain level (level A) started at the end of the Boreal phase, or at the beginning of the Atlantic phase (about 7-8 thousand years ago), as a result of which the active floodplain of the River Tisza was formed, and it was flooded every year before the water regulations and flood control of the 19th century. It is situated lower than level B by 3.7-4.8 m in the northern half of the Lower Tisza Region, but by 6.3-7.5 m lower at the estuary at the Danube. This lets us draw the conclusion that the incision started from estuary to the upper sections. The size of the channels in this floodplain level is much smaller (R_c= 0,3-1 km, L= 1,5-5 km, H= 1,5-2 km), which indicates that the bankfull discharge of the Tisza had decreased to 2-4 thousand m^3/s. The smallest channels are closer to today's flow of the river, and are only 1-2 thousand years old. The quick relocation of the channel can have happened easily in the central band along the river during higher floods, which is proved by the avulsion in the Serbian territory 1.0±0.1 thousand years ago, and 360±40 years ago next to Mindszent in Hungary (Hernesz and Kiss 2013). The presence of the smaller-size channels to the north of Novi Bečej can also be explained by the rearrangement of the flow direction of the River Maros during the Holocene, since it was relocated to the south app. 8 thousand years ago, thus its estuary can have been 60 km more to the south of today's estuary, around Novo Milosevo-Kikinda, and then it gradually shifted to the north. The increased slope and the large discharge played a role in the widening of the lower floodplain along the Tisza in its Serbian section.

Soil

The investigated area has diverse genetic soil types, similarly to their physical and water management properties. The dominant soil type is chernozem and its subtypes both in the Hungarian (32.91%) and the Serbian (77.87%) areas. The proportion of this dominant type is 62.46% in the total study area. There is a wide range of subtypes, calcareous chernozem and meadow chernozem being the most common among them (Fig. 2.7 on page 35).

A common feature of chernozem soils is the accumulation of humic substances, the crumby structure, and the two-directional movement of the calcium-saturated soil solution. The depth of the humic level shows a wide variety according to different areas and water impacts. The crumby structure resulting from the advantageous soil formation processes ensures good water and nutrient management. The water management features of the soil are very good. The physical appearance of soil belonging to this type, formulated on loess, is loam or clayey loam, and regarding their water management category, they have good or moderate water absorbing capacity, and good water-holding capacity. The common values of water absorption are between 70 and 150 mm/hour, and hydraulic conductivity is between 0.4 and 40 mm/hour. As a result of leaching processes, carbonate leaching can be observed from the topsoil, which leads to the reduction of the calcium content in the upper soil. Due to the high carbonate content these soils dispose of excellent acid-base and environmental buffer capacity.

The consequence of the differences of soil formation processes is the formation of different subtypes. To regard the entirety of the area examined, 19% are covered by calcareous chernozem. The name refers to the precipitated calcium found usually between 30 and 70 cm, which covers the structural elements of the soil as a membrane. These soils are the main areas of agricultural use owing to their excellent fertility. Due to the agricultural use of long years the ploughed layer (Asz) can have a degraded structure, and a compacted layer is formed at its bottom (plough sole). The plough sole layer has a significant negative effect on the water infiltration by its slow-down. The alkalinity of topsoil is neutral or slightly alkaline; its humus content is 3-4 %. The level A is dark brown, its humus content is constant. The transition into level B underneath is gradual, the organic content continuously decreases. Following this pattern, its colour becomes lighter, and its carbonate content increases. Their water management is very good, since each level has excellent permeability and water storage capacity, except for the over-cultivated level $A_{sz,}$ and the level of the plough sole.

The meadow chernozem soils account for 34% of the sample area. This type is distinguished from other chernozem soil types due to the weak water impact on soil formation. Due to the lack of oxygen, rusty and iron spots appear in level A, partly in the parent material. The humic level is brownish-black, black; the transition between the levels is sharply demarcated. The water impact influences the quality of the organic material, because a part of the organic material is present in the form of humic acid bound to iron. Calcium is predominant among the exchangeable cations, but the extent of exchangeable magnesium is not negligible, either. Groundwater under this soil type can usually be found at around 4 m depth, or a little higher. Because of this its water management is characterized by the upward flow of groundwater in one part of the year. It tends to overwet in the early spring period.

Owing to the soil types of the Danube-Tisza Interfluve blown sand area, sandy soils (blown-sand, humic sandy soils, and chernozem-type sandy soils) account for nearly one third of the Hungarian part, almost as much as the extent of chernozem soils. At the same time, this soil type represents a very small proportion of the Serbian areas, altogether only app. 2.5 %. Regarding the total study area examined the proportion of sandy soils is app. 20%.

The blown sand and the humic sandy soils belong to the main type of skeletal soils. They are characterised by very low organic and mineral colloid content, because of this their water management features are extreme: they dispose of strong water absorbing capacity, and weak water storage capacity. The values of water management features are as follows: their field capacity is under 15 tf%, and also their useful water resources, about 5-10 v/v. The speed of water absorption is more than 500 mm/hour, and the hydraulic conductivity has a similarly high value: (> 400 mm/hour).

The meadow soils are the second most common soil type (16.75%) in the Serbian part, while this soil type can be found in ~14% in the Hungarian part of the study area.

The periodic over-humidification plays a role in the formation of meadow soils. It can be the consequence of inland excess water, or nearby groundwater. The lack of air happening as a result of water impact triggers typical organic matter formation and the reduction of mineral components. The humus content is always black in the case of meadow soils, the reason for this is that humus formation mostly happens in anaerobic conditions. Two main reasons for leaching can be mentioned: gathering rainwater as a result of water runoff, and groundwater close to the surface. The leaching of the upper levels is frequent.As a consequence of anoxic conditions and over-humidification, the divalent iron compounds prevail. Bluish-greenish, so-called gley layers can be formed, which are poisonous for roots. Iron precipitations, rust stains are dominant in the layers above. The meadow soils can be characterized by sticky humic substances, difficult cultivation, the strong binding of phosphorus, and difficult nitrogen digestion in spring. The water management features of meadow soils are bad owing to their mostly clay, or heavy clay physical types. Their water absorption capacity is medium or bad in the majority of the cases, their water storage capacity is strong. The values characterising water management the best are as follows: field water capacity is between 42 and 50 v/v, useful water resource app. 10-15%. The speed of water absorption is low, 50-70 mm/hour, and the hydraulic conductivity is similarly low, 0.004-0.4 mm/hour.

Surface waters

The largest surface waterflows of the area are the Danube and the Tisza (Fig. 2.8 on page 39). The mean annual discharge of the Danube at Bezdan station (rkm 1426) is about 2,280 m^3/s, at Novi Sad (rkm 1255) is about 2,880 m^3/s, and at Smederevo station (rkm 1116), after receiving water from the Tisza and the Sava, it is about 5,490 m^3/s. The most important tributary on the Hungarian section of the area is the Duna-völgyi főcsatorna (Danube-valley Main Canal). The area between the two waterflows is crossed by an extensive network of canals, which is mainly connected to the Danube-valley Main Canal serving as a drainage channel of the accumulating surplus waters at the border of Duna-menti síkság (Plain along the Danube) and Homokhátság (Sandland). Most of the waterflows are qualified as artificial waterflows; they mainly follow the directions of the ancient Danube channels or the follow artificial channels on some sections. The most important tributaries of the Danube in Vojvodina are the Tamis and the Begej, which has its confluence below the estuary of the Tisza. The majority of waterflows are regarded as artificial waterflows. The average annual discharge of the Tamis at Pančevo, where it flows into the Danube, is about 50 m^3/s. The typical discharge of the lower section of the Tisza at Csongrád at low water is 115 m^3/s, at mean stage 550 m^3/s, and at the time of floods it can even reach 3,630 m^3/s, which means that the ratio of high water discharge is 30 times as much as the one of low water. The difference between the lowest and highest water stage is 10.29 m. The slope of water level is 2.9 cm/km, its flow speed (at Szentes) at low water is 0.1-0.4 m/s, at medium water is 0.6-0.9 m/s, while at high water it was measured as 1.5 m/s (Fiala et al. 2006). Its mean annual discharge at Senta (rkm 124) is about 810 m^3/s. An unfavourable feature of the Tisza regime is that in low waters the flow speed is extremely low, in the range of 0.15-0.20 m/s, and it is determined by the very slight slope of the river (only <1 cm/km) in the lower part of the river from the estuary of the Maros in Hungary to the Danube estuary (approx. 175km long section). The Novi Bečej dam built in 1975 modified significantly the water regime of the river.

The most important tributaries of the Tisza are the Maros River joining near Szeged, and the Hármas-Körös confluencing in the north-eastern part of Csongrád County. The Maros is a highly fluctuating waterflow, its water discharge at Makó during floods is 1,600-2,500 m^3/s, at mean stage it is 161 m^3/s, while at low water stage it is only 21 m^3/s. The Krijava, Čik, Kereš and Jegrička are the right-bank tributaries of the River Tisza in Vojvodina, whereas Begej and Zlatica are situated on the left bank of the river. The channels of the right bank, mostly artificial waterflows, follow the direction of north-west and south-east.

In Vojvodina there is a very extensive network of canals. In their length and capacity, the most important canals are the main canals of the multi-purposed Hydro-system "Danube-Tisa-Danube", whose basic functions are drainage and irrigation. The total length of these canals is about 700 km (Jojić 2002, Likić 2002). The Hungarian section of the area can also be characterized by an extended canal network. The canals in the region are temporary waterflows, similar to the small waterflows in the Great Hungarian Plain. During the drought-affected, longer or shorter periods water transport may stop, though some canals will not desiccate entirely in the most drought-affected years either. It is partially due to the fact that some canals are the receivers of cleaned wastewaters. On the other hand, channel beds of the canals, which do not run very deep, incise the groundwater level, thus they drain it. Another feature of the majority of canals is that they (unlike their natural bed slope) retard the waters due to high water stage at the estuary. Canals functioning this way are called double-operating (reversible) canals: they drain inland excess water in wet periods and they carry irrigation water to agricultural areas in arid periods (Rakonczai and Deák 2007).

Lakes can be found only in small areas in the Hungarian part (in Bács-Kiskun County it is 2.3%). The most significant lakes in the county are these: Szelidi-tó (Lake Szelidi), Vadkerti-tó (Lake Vadkerti), Földvári-tó (Lake Földvári) at Dávod, Felső-Kiskunsági tavak (lakes of Upper-Kiskunság) and the Kolon-tó (Lake Kolon) at Izsák. Besides them the oxbow lakes located in the floodplain of the Tisza need to be mentioned: in Bács-Kiskun County these are: Tiszakécskei-halastó, Lakitelki-Holt-Tisza, Alpári-Holt-Tisza, while in Csongrád County: Körtvélyesi-, Mártélyi-, Gyálaréti-, Atkai-, Nagyfai-, Serházzugi-holtág need to be listed. In the blown sand areas and on the border of them some saline lakes are located, which dry out if the weather is dry, and are filled up with water in wet periods. The most prominent of them is Fehér-tó (Lake Fehér) at Szeged. There is a swampy area running along the border of Homokhátság (Sandland) and the Duna-menti síkság (Plains along the Danube) (Turjánvidék in the north, Őrjeg in the south), which is a chain of deep-lying lakes running in north-south direction, being temporarily covered with water. Their extremely high ecological potential increases their significance.

Only small areas are covered with lakes also in Vojvodina, although there is a large number of natural and artificial lakes. Natural lakes in Vojvodina were formed by fluvial and eolian processes. A large number of oxbow lakes are situated both along the Danube and Tisza rivers. These lakes were formed by natural cut-off or by artificial cut-off during the river regulation works. The naturally cut-off oxbow lakes of the Tisza – the Rusanda (4 km^2), Ostrovo (3.5 km^2), Okanj (1.5 km^2) and Kopovo (1.45 km^2) – are among the middle sized lakes in Vojvodina. Along the floodplain area of the Tisza there are 13 oxbow lakes created by meanders being cut off artificially. According to their size and hydrologic function, the oxbow lakes Horgoška, Čuruška Mrtvaja and MrtvajaVrbica are the most prominent ones. Natural lakes of eolian origin in Vojvodina are: Lake Palić (5.6 km^2) and Lake Ludaš (3.3 km^2). Among the artificial lakes, the most significant multifunctional storage lakes were formed in the channel of smaller waterflows in Bačka (Zobnatica, Svetićevo, Panonija, etc.). Other artificial lakes e.g. fish ponds (Ečka, Sutjeska, Jazovo, Bečej, Bač, Futog, Kapetanski Rit, Velebit, etc.) and the lakes of Bela Crkva were formed in excavation pits (Bugarčić 1999, Bogdanović and Pavić 2003, Bogdanović and Marković 2005, Stanković 2005).

The spatial and temporal variability of the amount of surface water is increasing for the entire Carpathian Basin (Kiss and Blanka 2012, Sipos 2006). It is followed by an enhanced drought-hazard (for example in 2013 on the Danube) and prolonged low water periods. These will cause more economic, social and environmental problem also in the study area. As a summary, the annual water balance has shown a decreasing trend in the region owing to climate change both for the surface waters and sub-surface waters. The surface water runoff is of very small quantity for the most part of the year, which significantly contributes to the climate sensitivity of the area and also to the increase of water stress projected for the future. The decrease of river discharge can also be detected as a result of climate change (Sipos 2006, Kiss and Nagy 2012) (Fig 2.9 on page 42).

Vegetation

The determinant elements of the natural vegetation of the Great Plains used to be loess steppes, sandy steppes, floodplain forests, marshy forests and saline vegetation. Over the past two centuries, areas of significant extent have been included into cultivation, thus, relatively small areas of natural vegetation have remained. Due to the climate change in recent decades and to human activity, wetlands have been drying out in many places, which has been accompanied by the degradation and transformation of the vegetation.

In the Hungarian counties of the study area the Kiskunság National Park, the Danube-Drava National Park, as well as the Körös-Maros National Park deal with the management, research and conservation of the protected values and areas. The protected areas of national importance are the core areas of national parks, their landscape protection areas, their nature reserves, and the ex-lege protected areas as defined by the Act LIII of 1996.

The definitive elements of the natural environment of Csongrád County are the River Maros and the River Tisza, their associated oxbow lakes, and the remaining wetlands and salt affected wetlands. Sand steppe grasslands, interdunal wetlands, as well as some small-scale patches of loess steppes preserve the former natural landscape in the sandy area of the Danube-Tisza Interfluve. The core areas of national parks are: Cserebökény, Kardoskúti Fehértó, the steppes of Csanád, and the Maros floodplain.

Landscape protection areas (LP) and nature reserves (NR) of the county are:

- Mártély LP, Pusztaszer LP, Körös-éri LP
- Ásotthalmi Láprét NR, Pusztaszer Seven Chieftains NR; the extension of Lake Péteri Bird Sanctuary NR, Csongrádi Kónyaszék NR, Lake Péteri Bird Sanctuary, Pusztaszer Fülöpszék NR, Csanádi Puszták NR; Cserebökényi Puszták NR; Makó-Landori Erdők NR; Csongrádi Kónyaszék NR.

Natural values of Bács-Kiskun County are the salt-affected wetlands of the Danube valley, the sand steppes, sand dunes of the Danube-Tisza Interfluve ridge, and the alluvial forests of the Lower Tisza Region. Core areas of national parks are the steppe of Upper-Kiskunság, the lakes of

Upper-Kiskunság, the Lake Kolon of Izsák, the sand-dunes of Fülöpháza, the meadows of Orgovány, the sand-dunes and sand steppe of Bócsa-Bugac, Tőserdő, the oxbow lake of the Tisza at Szikra, the meadows of Peszér-Adacsi, and Miklapuszta; Gemenc and Béda-Karapancsa.

Landscape protection areas (LP) and nature reserves (NR) of the county are:

- Közép-Tiszai LP
- Habitat of the woolly foxglove of Bácsalmás NR, Császártöltési Vörös-mocsár (Őrjeg) NR, the geological exploration of Csólyospálos, Érsekhalmi Hét-völgy NR, Hajósi Homokpuszta NR, the meadow and loess bank of Hajós NR, Jászszentlászlói Kalmár-erdő NR, Kéleshalmi sand dunes NR, Kiskőrösi Turjános NR, Kiskunhalasi Fejeték Marshland NR, the Botrychium forest of Kunfehértó NR, Kunpeszéri Szalag-erdő NR, Lake Péteri NR, Lake Szelidi NR, Lake Dávodi Földvári NR.

The allocation of areas of European importance has been carried out in Hungary (Natura 2000 sites); according to the basis of their designation, they are special bird protection areas (SPA), and special areas of conservation and natural areas of special conservation interest (SCI) (Table 2.2 on page 45).

The studied part of Vojvodina is an agricultural region; more than 70 % of the area is used by agriculture. Natural and semi-natural vegetation cover only 20 % of the area (15 % of the area is forest or shrub and 5 % pasture). Therefore only small extents of protected areas exist in Vojvodina and these protected areas are fragmented and embedded into cultural landscape.

Larger protected areas are the Special Nature Reserve "Gornje Podunavlje" and the Subotica-Horgos sand area. The Special Nature Reserve "Gornje Podunavlje" is situated along the left bank of the Danube from the 1367 rkm to the 1433 rkm. It comprises the remnants of the former extensive floodplain of the Danube. The reserve represents a complex mosaic of water- and land ecosystems. The greater part of the reserve is covered by marshy, riparian forest complexes. This type of preserved indigenous biotopes is very rare, both in Serbia and in Europe. The reserve is an important centre of biodiversity.

The Subotica-Horgos sand area is the southeast part of the sand land between the Danube and the Tisza along the Serbian-Hungarian border. The typical forms are sand sheets, sand dunes and deflation hollows that were significantly modified by intensive agricultural production and forestation. The water flow of the area is Keres. The diversity of the area is given by forest and sand steppes and wetland habitats. The open water surfaces of two lakes near Subotica (Lake Palic and Ludas) provide resting and nesting place and food for migratory birds. Around the lakes reed, loess steppe and alkaline vegetation also occurs. As a part of Szelevényi Puszta near the border, forests of native and planted trees are reserved (Szelevény forest).

The flora and fauna of the cross-border areas are rather similar. The sandy areas are homes of rare plant species, like *Bulbocodium vernum*, *Dianthus superbus*, *Dianthus serotinus*, *Orchis morio* and several iris species. A significant European pond turtle (*Emys orbicularis*) population lives in the lakes and wetland habitats. *Riparia riparia*, *Merops apiaster*, *Alcedo atthis* rear their nestlings in carvings in the steep loess walls. There are significant *Vanellus vanellus*, *Podarcis taurica*, *Pelobates fuscus* populations here, as well. The flora of the Danube and Tisza floodplains provide an ecological corridor for wildlife.

The absence of mowing in deflation hollows in the blown sand area can facilitate the spread of reed and alien invasive weed (e.g. goldenrod). The lack of grazing in the sandy and loess meadows favours the spread of oleaster and acacia. Apart from ragweed, milkweed is a major problem in the abandoned fields. The indigo and the American ash in the floodplains may pose a major problem, or even flood risk.

2.2. Water management conflicts

János Rakonczai, Károly Fiala, Minučer Mesaroš, Anna Frank, Srđan Popov

A typical feature of continental climate is the high fluctuation in water balance. This is especially true for our study area. The region has had an average annual rainfall of 530-560 mm considering the last 80 years, but this is only a statistical average, in most of the years markedly different amounts of precipitation have been experienced. This means that a significant shortage of rainfall characterizes the large proportion of the years, while in other years surplus can be observed that can even cause serious damages. But the precipitation of a year on its own can also be very misleading. A good example of this is the year 2000, when the annual precipitation was the lowest in the above mentioned period (e.g. it hardly exceeded 200 mm in Szeged), but at the beginning of the year there were huge inland excess water inundations in the region – due to a lot of surplus precipitation in the second half of 1999. In addition, the specific topography and the lack of permanent waterflows in our region are capable of producing more water balance extremes. Perhaps the extremely wet year of 2010 is the most appropriate to exemplify this. The groundwater reserves of the blown sand area in the Danube-Tisza Interfluve can only be refilled from precipitation, and groundwater level have significantly decreased after the 1970s, probably caused by mainly climatic reasons. The significantly decreased groundwater level was not raised considerably by the effects of the 2010 wet season, and a considerable surface runoff from the higher parts of the area did not occurred, either. However, in the eastern parts of the blown sand area sloping gently to the east, some subsurface groundwater runoffs developed, which led to considerable inland excess water on the lower elevated eastern part of the blown sand area. All these clearly show that the special environmental conditions of the region itself cause that both extremes of water balance can occur - sometimes even at the same time. Beside the natural causes several human effects also contribute to the experienced water balance extremes.

Considering the above, the following main water conflicts can be identified in the study area.

- Extreme precipitation conditions, which sometimes lead to the development of inland excess water (with the problem of the drainage of surplus water), other times to long-term drying out of the waterflows of the area (mostly canals in natural depressions). All this cause that the wildlife of these relatively short (a few tens of km long) waterflows are in a very vulnerable state. But the different sections of one channel may have different hydrological condition. A good example for this in the Danube-Tisza Interfluve is that the channels did not transported water even during the year continuously humid 2010 in the higher parts of blown sand area, while on the lower reaches some (at least temporary) runoffs usually occur also in drier years.
- - The extreme rainfall activity can also generate conflicts in the drainage both in the outskirts and in the inner areas. Today, the principle of "drainage" dominates; the water management of settlements does not support the retention of useful water resources in the area of the settlement. The precipitation is led to the treatment plants through a

combined sewage network, and forwarded to the surface waters, together with cleaned wastewaters. This water resource, a significant one on annual basis, cannot be utilized. The rate of runoff increases together with the extension of paved surfaces, additionally the occurrence of extreme precipitation events increases, thus, aridification is intensified by an anthropogenic effect. The appropriate elaboration and implementation of rainfall management methodology is a priority in the region.

- However the canal network is relatively dense, the waterflows are hardly suitable for irrigation under the present circumstances. There are two main reasons for this. On one hand, despite the lowland character, the waterflows have a significant slope, that is, drainage occurs via gravity in the region, however, water supply from the direction of the Tisza is hardly possible (in the absence of sluices and pumps to ensure raising water). On the other hand, the quality of the water in the channels is often not suitable for irrigation for a variety of reasons.
- The local and regional water management has (will have) an important conflict: the increasing value and recycling of cleaned waste water. With the establishment of higher quality cleaning (using modern technology), broader and broader utilization of these resources will be possible due to the improvement of the quality of used water (gray waters). All this is especially important, since the valuable subsurface water is cleaned and then drained away with substantial cost after its extraction and relatively low utilization. By replacing the wastewater infiltration systems, the "support" of groundwater resources is stopped, thus, groundwater levels further decrease, together with the resources. The conditions and the methodology of utilizing gray water near its place of extraction need to be elaborated and implemented to protect the partially renewable water resources.
- The lack of surface water for irrigation during drought means that farmers irrigate from groundwater resources, which further enhances the lack of groundwater resources already declining due to climatic reasons. This will lead to regional imbalances because of the different rate of water level decrease experienced in the catchment area, since the water table can lowers below six meters in some places, so the extraction of groundwater resources will require more and more energy. This (in extreme cases) may negatively affect the population retention capacity of the region.
- A logical way of reducing surface water shortage in the area would be the retention of runoff. However, this is not easy for several reasons. The surplus water periodically emerging is accidental in time and space, the retention of excess water causes the deterioration of water quality (harmful salt content, nutrient or chemical leaching from soils, eutrophication), or may even contaminate the soils. In addition, farmers often think in the short term (and only in terms of their own interest), while water retention typically serves the interests of regional water balance.
- Regional water management is typically an environmental issue where intervention carried out in one location and often leads to changes (favourable or unfavourable) in others. An example of this may be that the increased groundwater abstraction in Vojvodina has caused well-documented permanent groundwater level decline in the south-east of the Danube-Tisza Interfluve blown sand area.
- It is very difficult to convince farmers to save water, if their business does not suffer from the negative effects of water exploitation, or they do not make profit from saving water.

- The "inflexibility" of water authorities sometimes does not help to solve the water problems, either. The regional water experts often know what kind of interventions would help efficient management of water resources the most, however, a number of administrative rules, inflexible decision-making mechanisms, ownership relations, and conflicts of interest hinder their work.

In Vojvodina based on thickness of subsurface aquifers, the quantity of water available for exploitation can be estimated. The highest conflict can occur in case of municipalities on water-supply layers less than 20 meters (Fig. 2.10 on page 51). Due to the limited aquifer and the huge consumption, approximately half of Vojvodina has a conflict of reserves and water consumption. The number of inhabitants in the zone of high conflict is 179 399, and 729 955 in the zone of moderate conflict respectively. The total number of inhabitants under conflict in Vojvodina is 909.354, approximately half of the total population.

Further conflict is the slowing of river transport due to low water stages. For example, on the River Sava, transport completely halted in September 2012 between Sremska Mitrovica and Šabac, and on the River Danube, the water level was near the lowest limit for safe passing in the vicinity of Pančevo in August 2012, and larger vessels (barges, tankers) were stopped.

The water shortage affected irrigation and livestock supply as well. In the southern parts of Serbia water supply shortages were also observed in settlements – increased consumption occurred due to the heat wave coinciding with the lowest water levels in rivers. The mostly affected cities were: Prokuplje, Niš, Požarevac, Nova Varoš, Novi Pazar, Veliko Gradište, and some parts of Belgrade.

Decreased hydropower output was experienced in energetics due to low water levels of the River Danube, Drina and Lim. Record levels of power consumption occurred due to the heat wave coinciding with the drought, and 20 % lower power output prompted the need for power import.

2.3. Landuse conflicts

Péter Szilassi, Srđan Popov

Considering the concept of land use conflicts different definitions can be found both in Hungarian and international literature. According to Hungarian publications on landscape planning (Csemez 1997) land use conflict occurs when the current use of land does not coincide with landscape attributes (landscape function). In such cases overuse may often develop, which eventually leads to the degradation of the landscape and the decrease in the landscape attributes (landscape potential). Csemez (1996) differentiates three basic forms of land use conflicts:

(1) Functional land use conflict, which develops when there is a contrast between social needs, expectations and the optimal land use originating from landscape attributes;
(2) Aesthetic conflict, which develops when land use does not fit to landscape character, destroying its aesthetic value;
(3) Landscape ecological conflict, which develops when the given land use irreversibly decreases the species richness, respectively causing habitat degradation.

From land use conflicts, the lithosphere can be characterized by the conflict derived from mining activities. On the plains, mainly mining of sand used for road building, and mining of gravel from river basins are significant. At several places lakes can be found in former places of mining, which serve a touristic and ecological function even today. Embankments of sand mines provide nesting places for birds in many cases. In the lack of industrial activities, positive forms are uncharacteristic; only the environmental impact of waste dumps on the plains implies a source of conflict today. Conflicts of the hydrosphere have both qualitative and quantitative features. Qualitative problems are caused by the admission of communal and industrial sewage into still waters and living waters, and also the effects of fertilizers, which can cause significant pollution in several still waters in the region and facilitates eutrophication. Quantitative problems are caused by the growth in water demand and water extraction, as well. For irrigation, both ground-water and surface water (from rivers and irrigation canals) are used in the region. Due to river controls and drainage discharges in the last century, the population gained a relevant amount of arable land. With the drainage of the lower-elevated, waterlogged areas the highly elevated arable lands have become absent of water cover. However, with the lack of water cover, a change and degradation in the vegetation and wildlife of the wetlands has begun. This is a source of conflict even today, since water cover would be optimal for the natural vegetation. However, owing to water retention, cultivated areas may be flooded as well, which has economic consequences for the farmers. Considering the conflicts of the atmosphere, in the lack of significant industrial production, high pollutant emission is uncharacteristic to the study area; only the environmental impact caused by transport on busy roads may imply more notable problems. Among the conflicts of the atmosphere, the dust load in the air is the most relevant problem. Apart from the dust coming from transport, the amount of dust deriving from cultivated areas is also significant. Considering the biosphere, the situation of environmental protection could be emphasized in the first place. Due to drainages, most of the area has been cultivated, the natural areas are fragmented, the number of broad and continuous natural areas is low, and the ecological corridors have an excessively important role. Natural forests can scarcely be found; the exceptions being the floodplains. On the blown sand part of the study area forest plantations are common, mainly acacia and pine forests have been planted. Outside the floodplain area, dry grasslands and wet meadows have remained. The chernozem soils of Vojvodina have become cultivated almost completely. An increasing land abandonment of sandy fields can be observed in the highly elevated areas, due to the decrease of ground-water level noticeable in the Danube–Tisza Interfluve. In turn, the remaining wet habitats provide home for several species of plants and animals even today.

The urbanization in the 20th century brought further land use conflicts. Due to the spreading of resort and residential areas the expansion of built-up areas has increased. Consequently, the water balance (increasing extraction of ground-water, the changing of evaporation and runoff conditions on built-in surfaces, the effects of canalization), and temperature conditions have changed in surrounding areas; air and noise pollution due to transport and the disturbance of natural areas have also increased around cities.

Although the role of the countryside has started to be more appreciated in the past decades, land management is not yet a common practice in the region. Rather, intensive agricultural production is in the focus because of the good soil properties, and keeping livestock and grazing are of minor importance. In connection with intensive agricultural production, the degradation of the soil implies a land use conflict, the main reasons for which in the region are the expansion of settlements, industrial, mining and transport facilities, erosion (wind, water), salinization of soil, and loss of nutrients.

In order to turn conflict-free, sustainable land use into common practice in Vojvodina and the Southern Great Plain, it is necessary to analyse the complex economic and social effects of drought to prepare the appropriate decision. Among the social and economic problems caused by drought, the most marked one is dramatic drop of the agricultural yields in drought years (Fig. 2.11 on page 55). It is an unquestionable fact that the economic branch most sensitive to the region's climatic conditions is agriculture, and within that, crop production.

Due to the increased climate sensitivity of the agricultural areas in Vojvodina and the Southern Great Plains, it is a question of great importance to examine the sensitivity of the mainly agrarian lands during regional, town-level planning (Bussay et al. 1999, Rakonczai 2006, Láng et al. 2007) (Fig. 2.12 on page 56). The most characteristic soil type in the Danube-Tisza Interfluve blown sand area is blown sand. The fertility of humic sand soils richer in humus is low due to the extreme water management characteristic of sands and the small nutrient capital compared to chernozem soils. The drought sensitivity of these areas may be increased. For this reason, the proportion of arable land is lower in this area. In case of saline soils, there is a dominance of solontsak and solontsak-solonets soils. Water-soluble salts, especially sodium salts play a great role in the development of the characteristics of these soils. The accumulation of salt is a consequence of dry climate or salty ground-water near the surface. These areas are protected natural areas, meadows and pastures, where the decrease of water cover (due to water scarcity) may cause serious changes. We can consider the chernozems to be the dominant soil type in the study area, which are the most fertile. They are the least subject to the effects of drought. Since these areas have favourable fertility, they are almost completely under agricultural cultivation. Greater droughts can cause yield loss, thus the most significant economic damages may occur in this area.

2.4 Landscape sensitivity

Gábor Mezősi, Zsuzsanna Ladányi, Viktória Blanka, János Rakonczai, Burghard Meyer

Introduction

Due to climate change physiological, phenological, species distribution changes and ecological stability problems in several ecosystems are detected (Menzel and Fabian 1999, Hughes 2000). In the long run decreasing ecological stability results in decreased biodiversity, species loss or declining ecosystem services (Kovács-Láng et al. 2008). Climate change highly influences natural areas that are near to the limits of hydrological conditions due to the increasing temperature and changing precipitation characteristics. Such areas are e.g. wetlands where water is important limiting factor; the ecosystems get out of equilibrium state permanently and start to degrade due to decreasing precipitation. In addition, increasing abiotic (fires, floods, storms, heat-waves, droughts, etc.) and biotic (e.g. pest outbreaks) disturbances following a rapidly changing climate might accelerate ecosystem disruptions (Hobbs et al. 2006).

Sensitivity and potential vulnerability can be estimated by landscape indicator approach that integrates landscape ecology and related disciplines to the assessment of vulnerability and sustainability of ecosystem processes and functions (Pitchford et al. 2000). Landscape indicators and landscape approaches are successfully applied in environmental monitoring and by the help of this approach patterns and relationships can be revealed that are not intuitive or readily apparent from a priori knowledge of landscape (Clagett et al. 2007).

Our aim was to analyze the sensitivity to drought of different landscape types and especially the protected areas in the Danube-Tisza Interfluve using an indicator approach. The sensitivity was assessed by soil water regime, available groundwater resources, biomass production of vegetation and wind erosion hazard indicators separately. The results were summarized into a combined sensitivity map, representing the affecting factors according to land use classes and for the protected areas.

Study area and methods

The study area (Fig. 2.13 on page 59) is an important region of the Pannonian Biogeographical Region in the Carpathian Basin because it is a biosphere reserve developed on fluvial sediments of the Danube. It consists of four larger landscape units: the center part covered by sand sheets and sand dunes (Kiskunság), the northeastern part covered by loess determined by soils with good fertility (Bácska-Plain), furthermore the alluvial plains of the Danube and the Tisza.

The landscape is sensitive to the natural and human-induced changes. One of the most important environmental factors is the climate and its recognized changes (Bartholy and Pongrácz 2007), which were enhanced by intensive anthropogenic activities, such as the river regulations and flood protection in the 19th century, the drainage of surface water inundations in the middle of the 1900s, and groundwater overexploitation to serve social and agricultural demands. The increased aridity and the anthropogenic factors contributed to the decrease of the groundwater table (Pálfai 1994, Rakonczai 2007), and the open water surfaces (Kovács 2008). The water shortage resulted in significant alterations (e.g., soil and vegetation in the case of alkaline and non-alkaline wetlands (Iványosi 1994, Biró et al. 2008, Puskás et al. 2012).

Landscape indicator approach was applied for the assessment of landscape by setting up a landscape indicator model using dependent variables and landscape metrics. The landscape indicators are used for hot spot identification and area-wide assessment. The sensitivity of the areas to drought is defined in this study mainly by soil water regime, available groundwater resources, biomass production of vegetation and wind erosion hazard; thus, these indicators were assessed during the analyses. The indicators characterize both the abiotic background and the response of the vegetation; therefore, they can describe sensitivity to climate change influencing the different types of management. Sensitivity assessment was carried out on both on landscape and protected habitat/land use scale. The regionalization was defined on the basis of landscapes, while land use and land cover were classified by Corine Land Cover 2006.

The sensitivity of the soil to CC is greatly determined by its water-holding capacity and water infiltration because it influences the available water resources for vegetation in dry periods. Based on the agro-topographical map, three types of soil water regime were defined. The soils with problematic water regime were regarded as sensitive to CC having very high water infiltration and weak water-holding capacity or very low water-holding capacity and limited water infiltration. The available groundwater resources were estimated using the groundwater table. The groundwater level in the arid years 2003, 2007 and 2012 was compared with the average in the period 1970-1975. Areas where the decline was over 1 meter were regarded as sensitive. In this case, the availability of water is limited for the vegetation and can cause the alteration of certain soil types (salt-affected soils, meadow soils). The annual biomass production reflects the sensitivity of the vegetation because its decrease indicates the reaction of vegetation to dry years. The average annual biomass production for the period 2000-2012 was calculated from enhanced vegetation index (EVI) values, and the deviation in the arid years of 2003, 2007 and 2012 to the average was counted. The areas where the negative deviation of biomass exceeded 5% in the investigated arid years were considered sensitive. The applied wind erosion hazard map uses the erodibility of soil, vegetation cover and the occurrence of erosive winds by a fuzzy logic based method to estimate the sensitivity (Mezősi et al. 2013). The indicators were evaluated on the basis of landscape types according to the predefined classes. The analysis was performed for each indicator separately and they were summarized to define the rate of sensitivity. The sensitivity was categorized from 0 (lowest sensitivity) to 4 (highest sensitivity) depending on the presence of one or more indicators affected.

Results

Soils having an extreme water regime in the study area (Fig. 2.14 on page 61) are mostly salt-affected and sandy soils. In the case of salt-affected soils clay mineral and sodium content, in the case of sandy soils high permeability are the reason for the extreme conditions of the problematic water regime. The alluvial fan with blown sand is mostly determined by soils with extreme water regime (79% of the area). In the case of the other two landscapes, their percentages are not as significant (22% in case of the alluvial plain and 28% in the loess plain), and the land use types are affected in different proportions. The soils with problematic water regime are characteristic for the protected areas (mainly salt-affected areas) in the alluvial plain and for protected areas and non-protected forests in the loess plain. Arable lands are also found on such soil types (meadow soils and chernozems with saline subsoil) in the loess plain and the landscapes along the rivers; however they represent only a small percentage of the total area.

The decrease of the groundwater table influences the higher-elevated part of the interfluve and thus, the landscapes of the loess plain and the alluvial fan with blown sand. These areas are affected to a similar spatial extent (53% in case of loess plain and 64% in the alluvial fan with blown sand). In blown sand landscape mostly dune region covered by non-protected meadows and forests are found in such morphological conditions, while on the loess plain other agricultural areas are also affected.

All three landscapes were highly affected by the decreased biomass production. The highest spatial extension of the affected areas was detected in the case of the loess plain (84%) because the percentage of arable lands is the highest in this landscape; 90% of them showed significant decline. The alluvial plain and the blown sand areas were affected at similar percentages (66% and 62%). The significant decrease of biomass production in the alluvial and loess plains confirms the effect of drought on the cultivated plants that are unable to adapt to the extreme weather conditions. Furthermore, the significant yearly decrease can also be caused by the variability of crops year-by-year. The natural (and semi-natural) habitats show a higher decrease in the case of the blown sand areas and the alluvial plain. There are no significant differences among the landscape types in the percentages of the affected land use types. Decreased biomass production was observed on more than 50% of all land use categories except forests (30-40%) in arid years, confirming the increased sensitivity of the study area.

The significant difference in wind erosion hazard of the landscapes is caused by the differences in erodibility of the dominant surface sediments. The alluvial fan with blown sand and the sandy patches in the loess plain are mostly threatened by this indicator. Forest areas are not endangered, so they contribute to the decrease of the affected areas. By overlaying the results of the investigated indicators (Fig. 2.15 on page 63), landscapes of the study area have different rates of sensitivity to CC. The alluvial fan with blown sand shows the highest sensitivity, where the 4 indicators overlapped in the highest percentage. The alluvial plain is the least-affected landscape type, where 50% of the area is not sensitive to any of the indicators. The loess plain is moderately sensitive, natural protected habitats covering only 17% of the area. 2% of the protected areas proved to be sensitive in the study area. Slight sensitivity (1 indicator) is detected in 30% and moderate sensitivity (2 indicators) in 36% of the protected areas, and 16% (3-4 indicators) of the area showed high sensitivity. The most sensitive areas are located in the highest and the transitional zone between the sandy area and the alluvial plain, and they are mostly wetlands and the sand-dune regions.

The overlapping of 4 indicators is characteristic on the highly elevated blown-sand areas. The dunes are mostly covered by sand steppes, and the interdunal depressions are characterized by wetlands. Due to the high sensitivity to the drying of the climate, consequences at the highest elevations have been detected even the last few decades: the wetland vegetation has been transformed and degraded (e.g. Molnár 2003). Here, the vegetation has already adapted to the changed conditions, or drought tolerant steppe vegetation occurs; therefore, less change in the vegetation is expected in the future. In case of forests decreasing water resource is expected due to increasing drought hazard, therefore, the water demand of planted forests in the future has to be considered (planted acacia and pine having lower water demand compared to native oak and poplar trees). The possibility of forest fires will increase in the future. Furthermore, dry steppes are threatened by the spread of adventives and wind erosion in the case of sparse vegetation. The overlapping of 3 indicators occurs on sand steppes and some interdunal wetlands of highly elevated sand regions. Here, biomass decrease is less compared to areas with 4 indicators due to local depressions.

Two indicators overlap in case of mostly wetlands closer to the rivers and in local depressions. On the eastern part of the area wetlands are more fragmented, which enhance their vulnerability. Increasing drought hazard highly affects wetlands, causing increased water shortage and decreased annual runoff. The lack of water (both soil moisture and groundwater resources) will result in the alteration of water and salt transfer and the degradation of water-related salt-affected soils. This means changes in distribution and composition of the species and habitat pattern, and thus the relevance of Ramsar sites will increase (Erwin 2009). Since soil water content of wetlands is expected to remain higher than average under the changing climate change conditions, therefore they will have an important buffer function under the projected climate change. They are essential for local climate and water regulation and their status should be preserved (Holsten et al. 2009). The further decrease of open water surfaces is expected in the future and the changing water regime can result in their drying out. On the basis of the calculated indices, sensitive areas are located in the highest parts and the transitional zone between the highly elevated sandy area and the alluvial plain. Similar findings were described by Rakonczai et al. (2012) using habitat extension and habitat quality data.

One or zero indicator is characteristic in case of wetlands at lower elevations (on the alluvial plains) categorized as slightly sensitive on the basis of the indicators and the extreme water regime or the decrease of the biomass production are mostly responsible for the sensitivity there. However, they also could become vulnerable due to future climate change. In these areas the vegetation can adjust to the arid and humid years; the favorable conditions contribute to the regeneration and sustainability of the habitats. The regeneration potential of these wetlands is reduced due to the tendentious drying of the climate. These areas are mostly endangered wetlands that are dynamic systems closely connected to ground water. Wetland habitats are highly sensitive to CC: in case of increasing aridity their alteration is expected (Essl et al. 2012, Rakonczai et al. 2012). The degradation of these wetlands are already detected, since the decrease of open water surfaces (mostly alkaline lakes) was observed also on the alluvial plain not only on the blown sand areas, which also confirms that CC strongly affects these landscapes.

Closer to the Tisza and Danube Rivers the decrease of the groundwater level does not affect the landscapes because of their topographic position. In case of the floodplain forests of the Tisza and Danube Rivers zero indicators were indicated owing to the favorable environmental conditions. Water resources are easily available, thus the floodplain habitats can tolerate the changes of climate parameters. These can contribute to long term sustainability of these habitats. The wetlands along the border of the blown sand area and alluvial floodplain of the Danube River was identified as not sensitive based on the indicators, because they are located in filled-up paleo-channels of the Danube River and regional groundwater flows also supply their water balance. These wetlands can be sustainable in longer term due the better hydrological conditions; therefore management should take particular attention to the water control and conservation of these wetlands. Lakes closer to the rivers also not show sensitivity based on the indicators.